AGENT-BASED MODELING OF SMALLPOX EPIDEMIC CONTROL STRATEGIES

Secretary's Council on Public Health Preparedness

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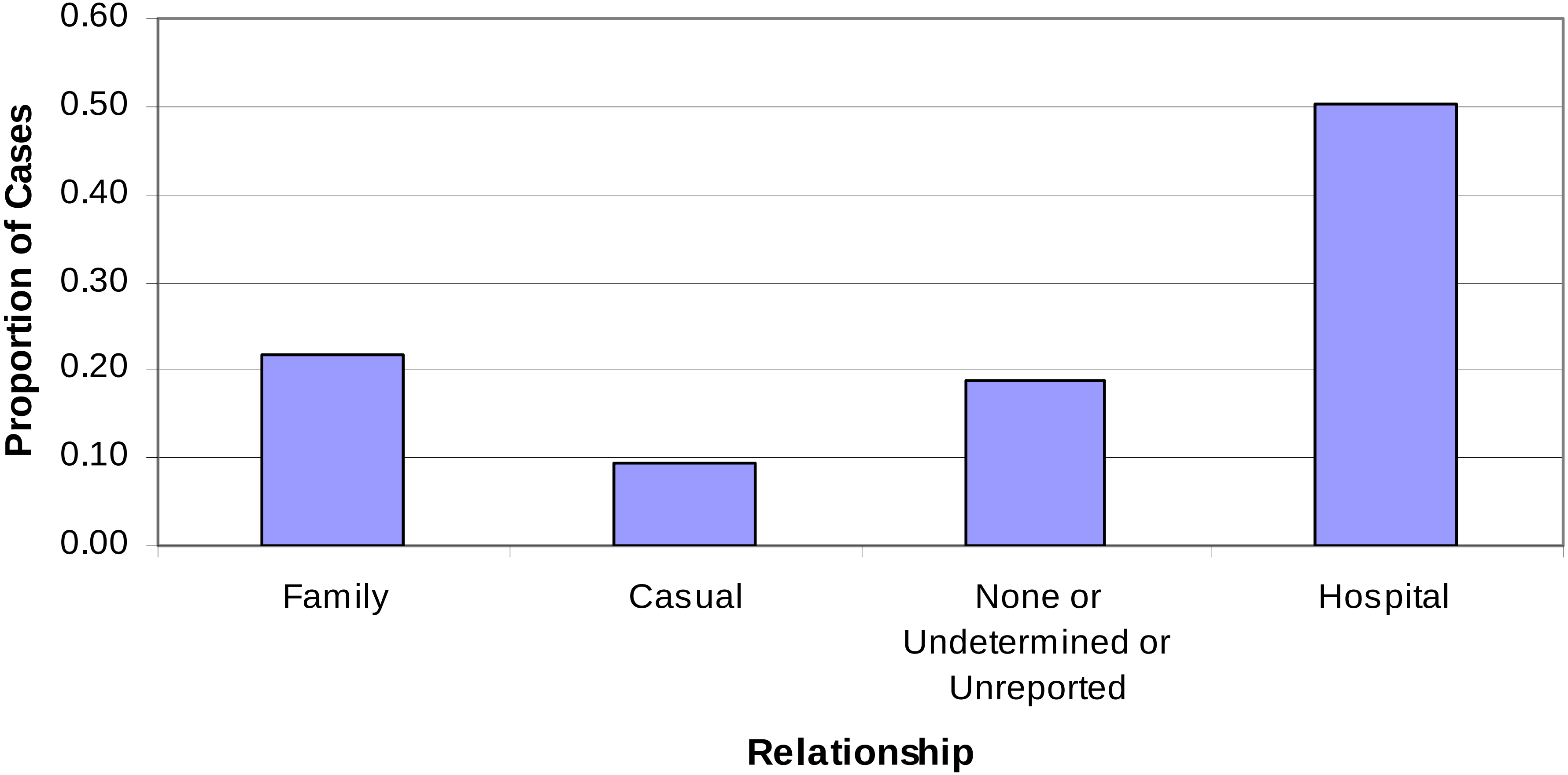
Smallpox Cases by Relationship to Transmitting Case for 680 Cases Occurring in Europe 1950-1971 (Mack, 1972)

Key role of households and hospitals



County-Level Model: 800 individuals

- 2 Towns
- Per Town Assumptions
  - 400 people comprised of
  - 100 Households, each with 2 adults and 2 kids
  - Non-commuting adults work at the town workplace
  - 10% adults of commute to the other town’s workplace
  - 5 adult hospital workers
  - Kids go to school in the town school
  - 1 workplace
  - 1 school
- 1 Common Hospital
  - 10 adult hospital workers
- 1 Common Morgue

Individuals on screen change color as they become infected and progress through the stages of smallpox

Susceptible

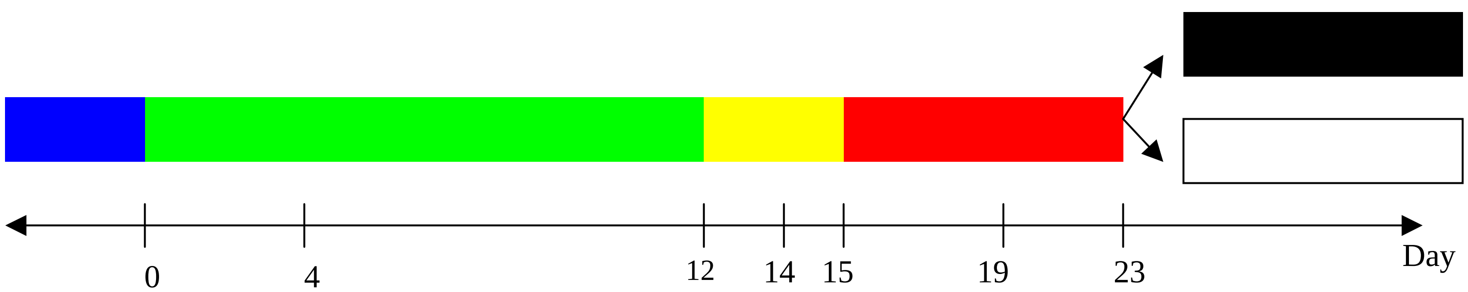
Infected, Asymptomatic, Non-Contagious

Infected, Febrile, Contagious, Early Rash / Pre-Diagnosis

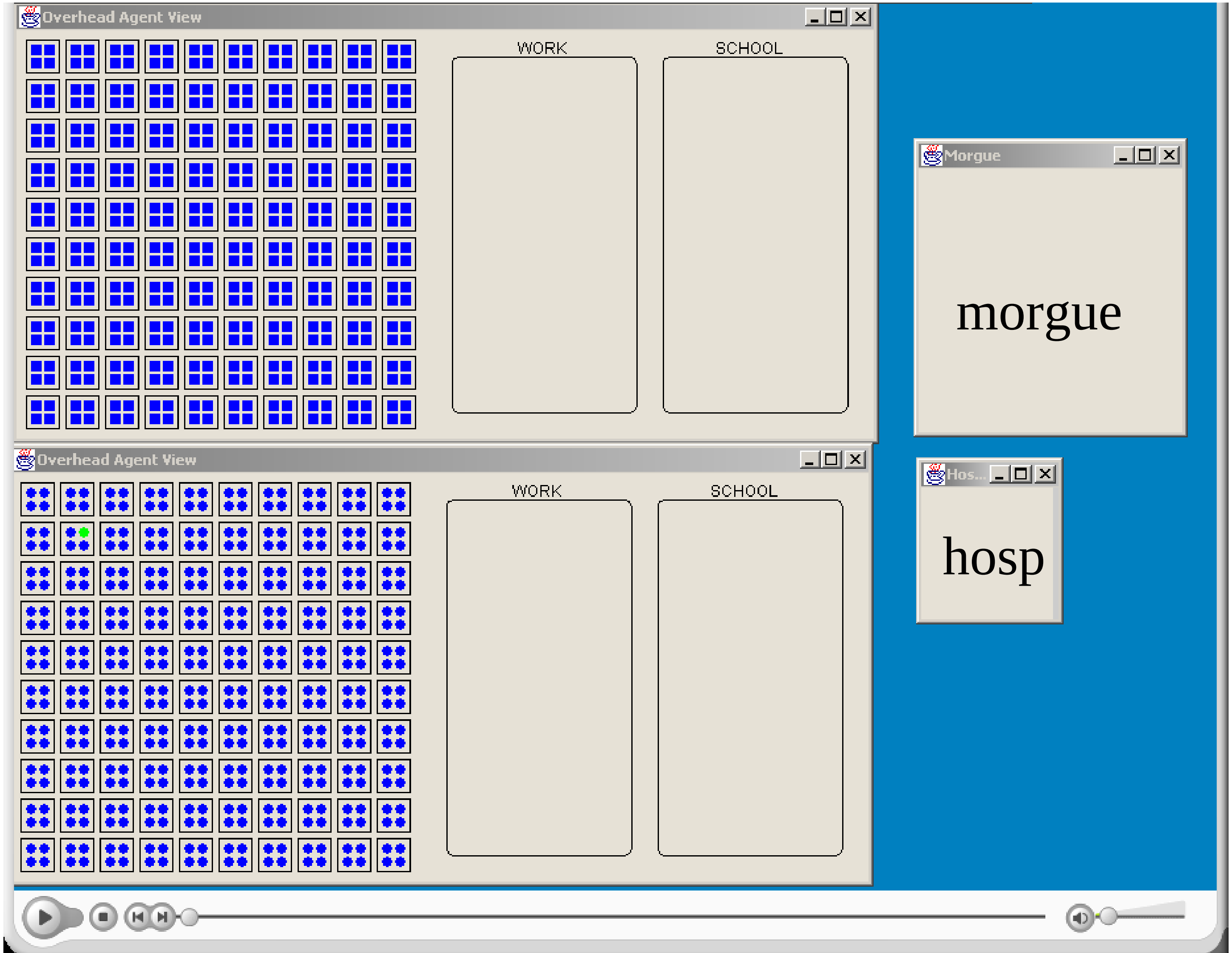
Infected, Febrile, Contagious, Rash / Diagnosed

Dead

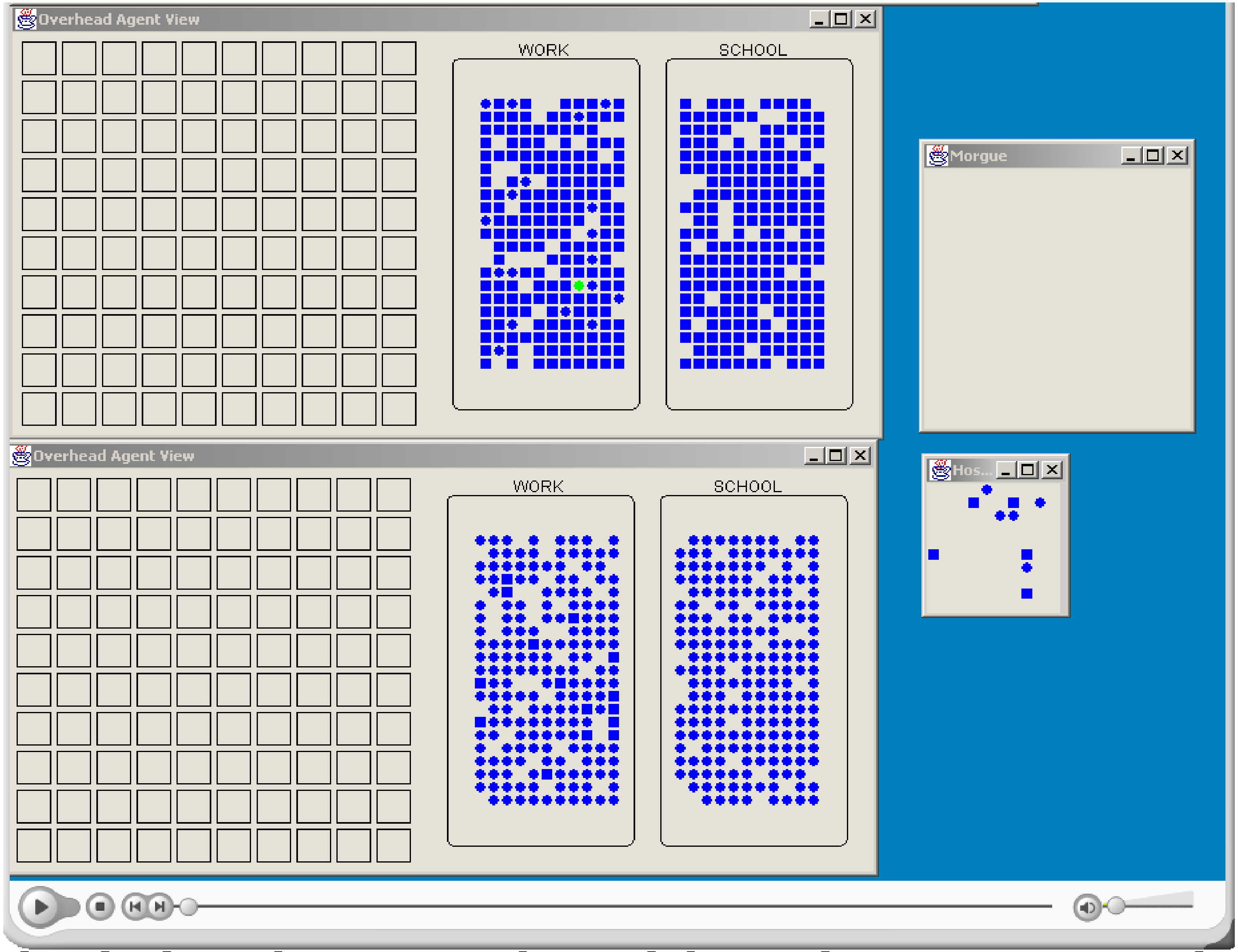
Recovered and Immune



Computer screen at start of model run: one infected individual
[N.B. “night-time” = all individuals at home, not at work or school

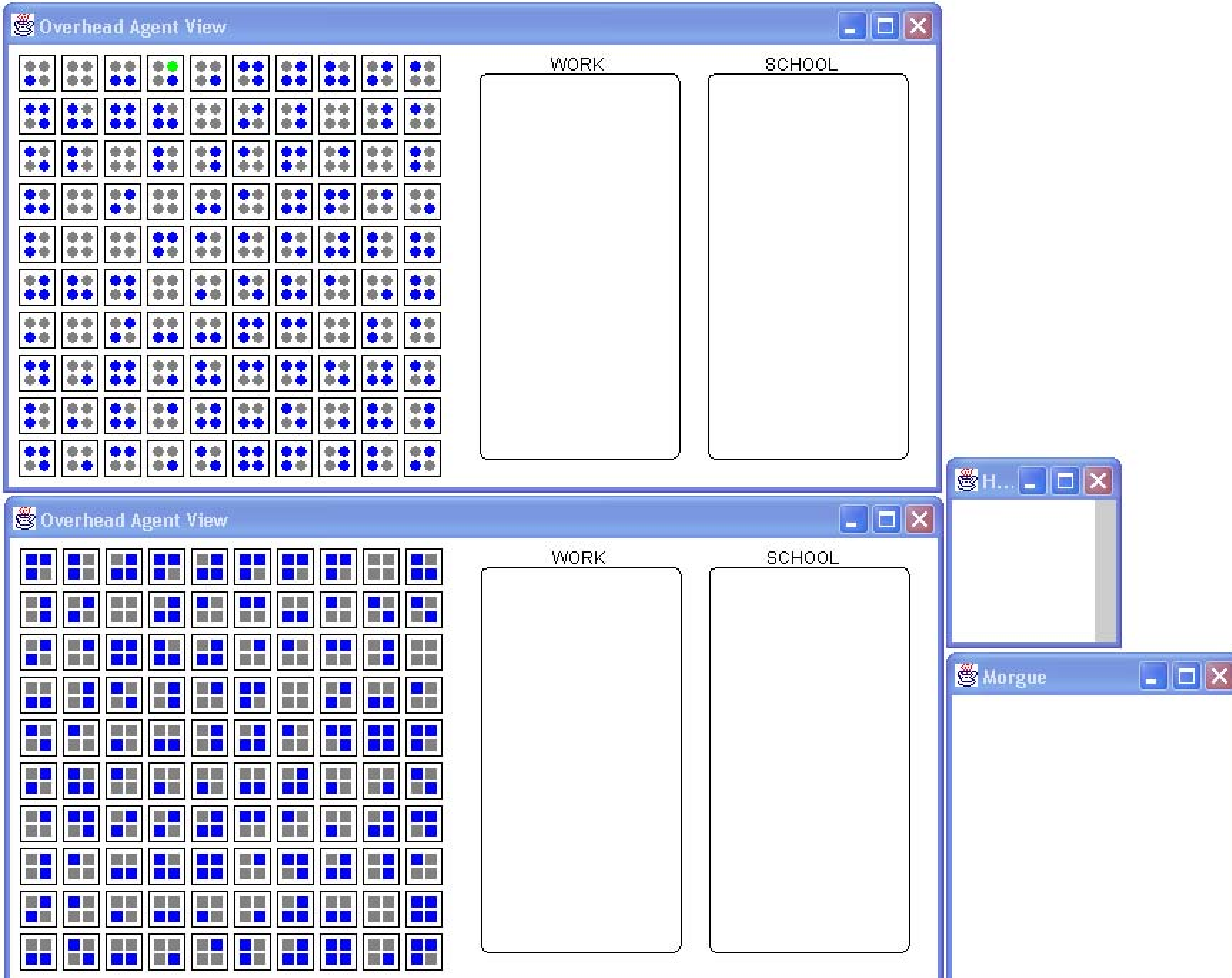


Computer screen on DAY1 of model run: one infected individual
[N.B. “Day-time” = all individuals are at work or school



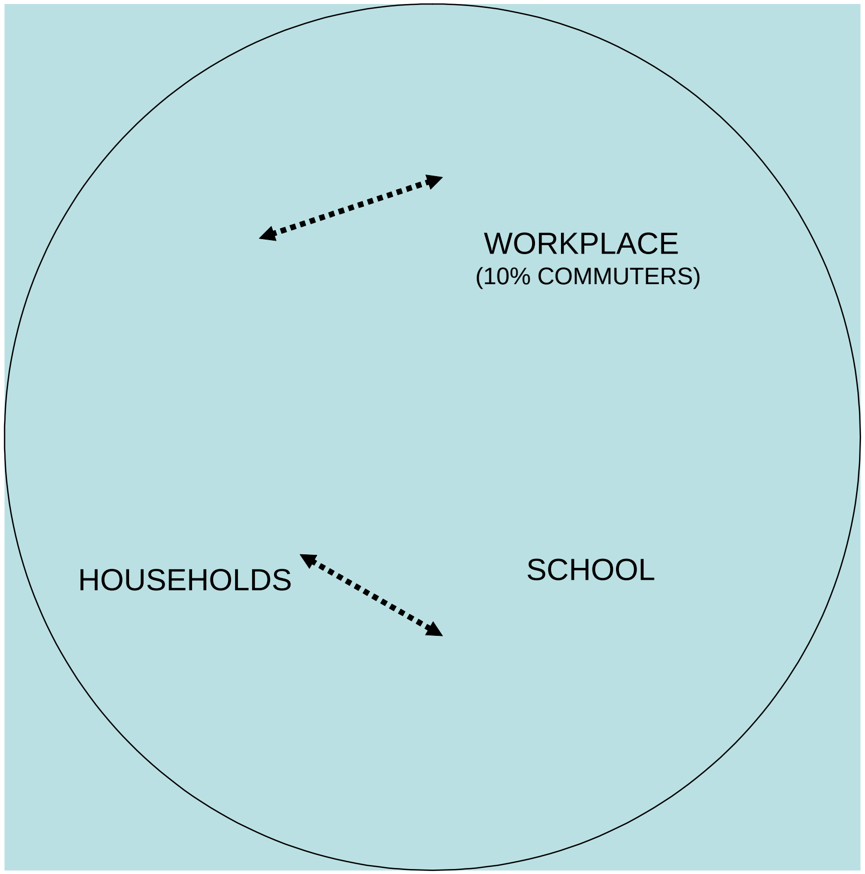
All individuals go home at night, and the cycle repeats every “day”

Computer screen well into the epidemic

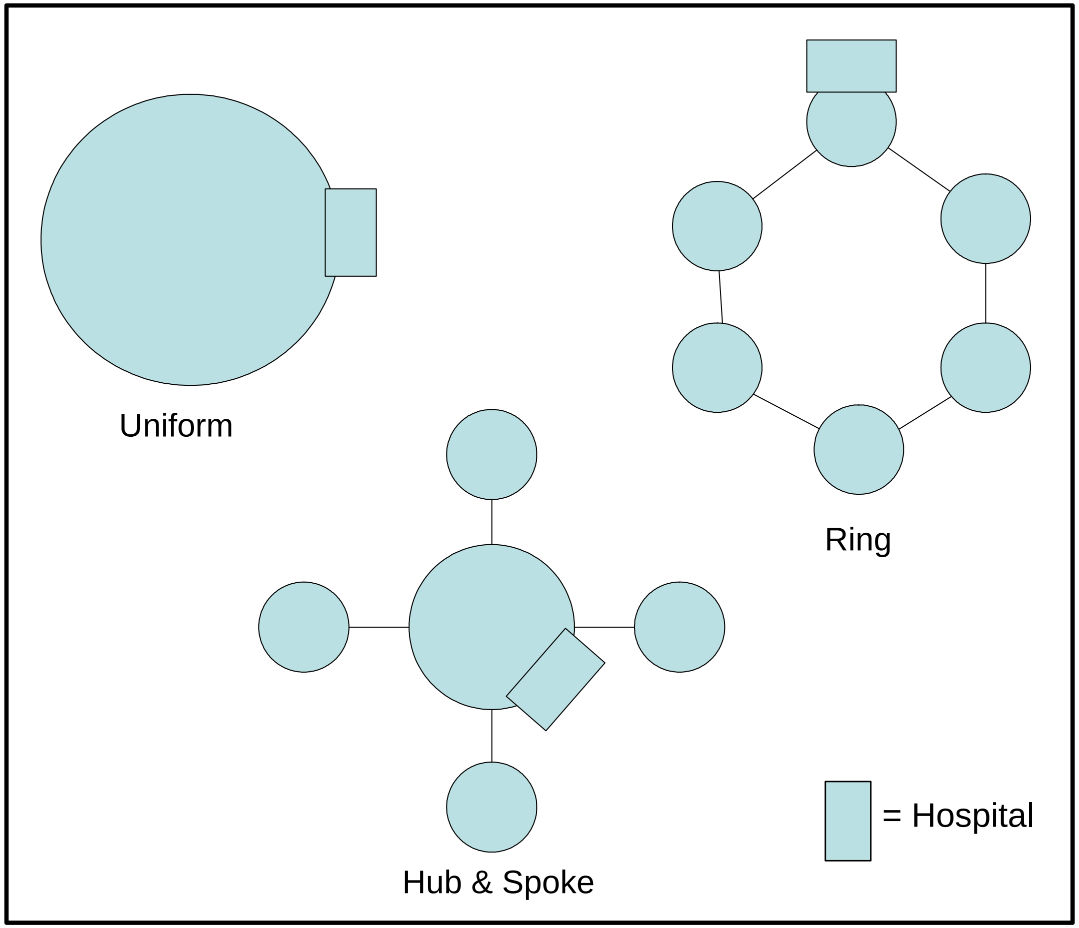

Overhead Agent View
WORK
SCHOOL
Overhead Agent View
WORK
SCHOOL
H...
Morgue

Schematic summary of scenarios examined

	Scenario									
	1	2	3	4	5	6	7	8	9	10
Background Immunity	No	Yes								
Household contact trace 100%			Yes							
Work/school contact trace 75%			Yes							
Hospital Vac & Isol (>20d)			Yes							
Preemptive Hospital Vaccination				10%	50%	10%	50%	10%	50%	10%
Reactive School Closure 10 d						Yes				
Mass Reactive Vaccination						40%	40%	80%	80%	None

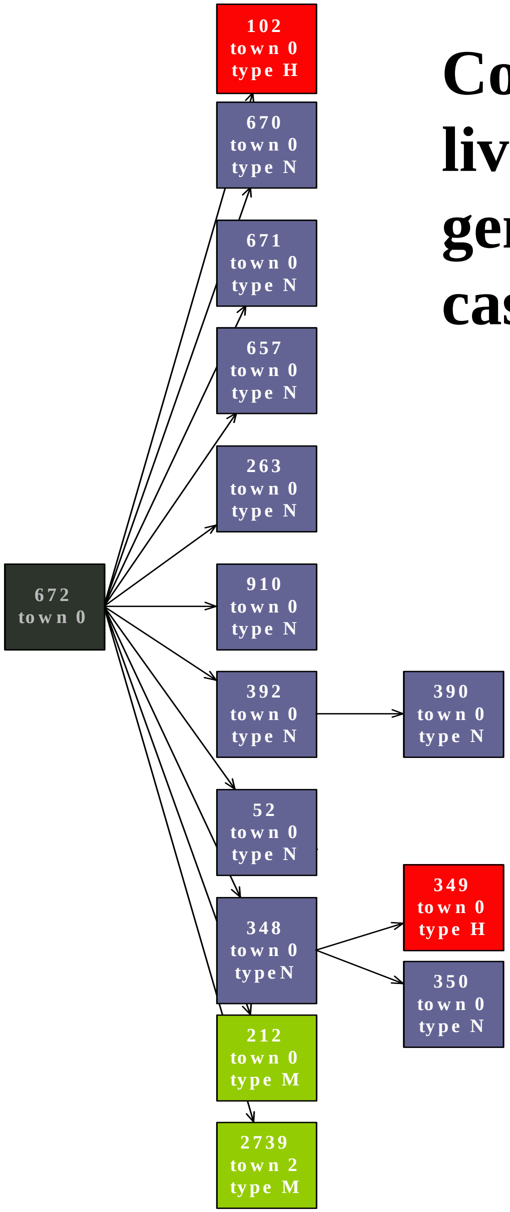


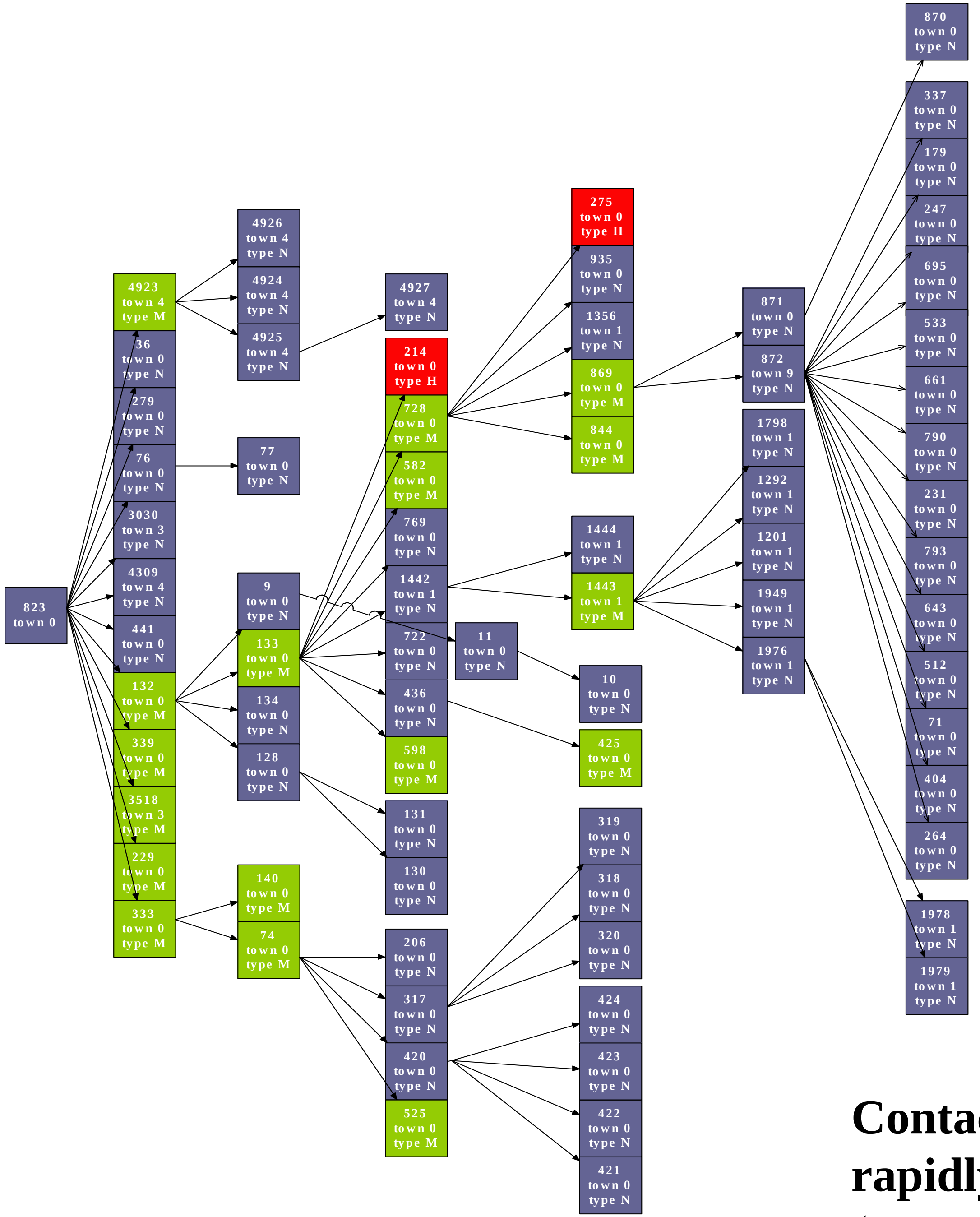
Basic social unit



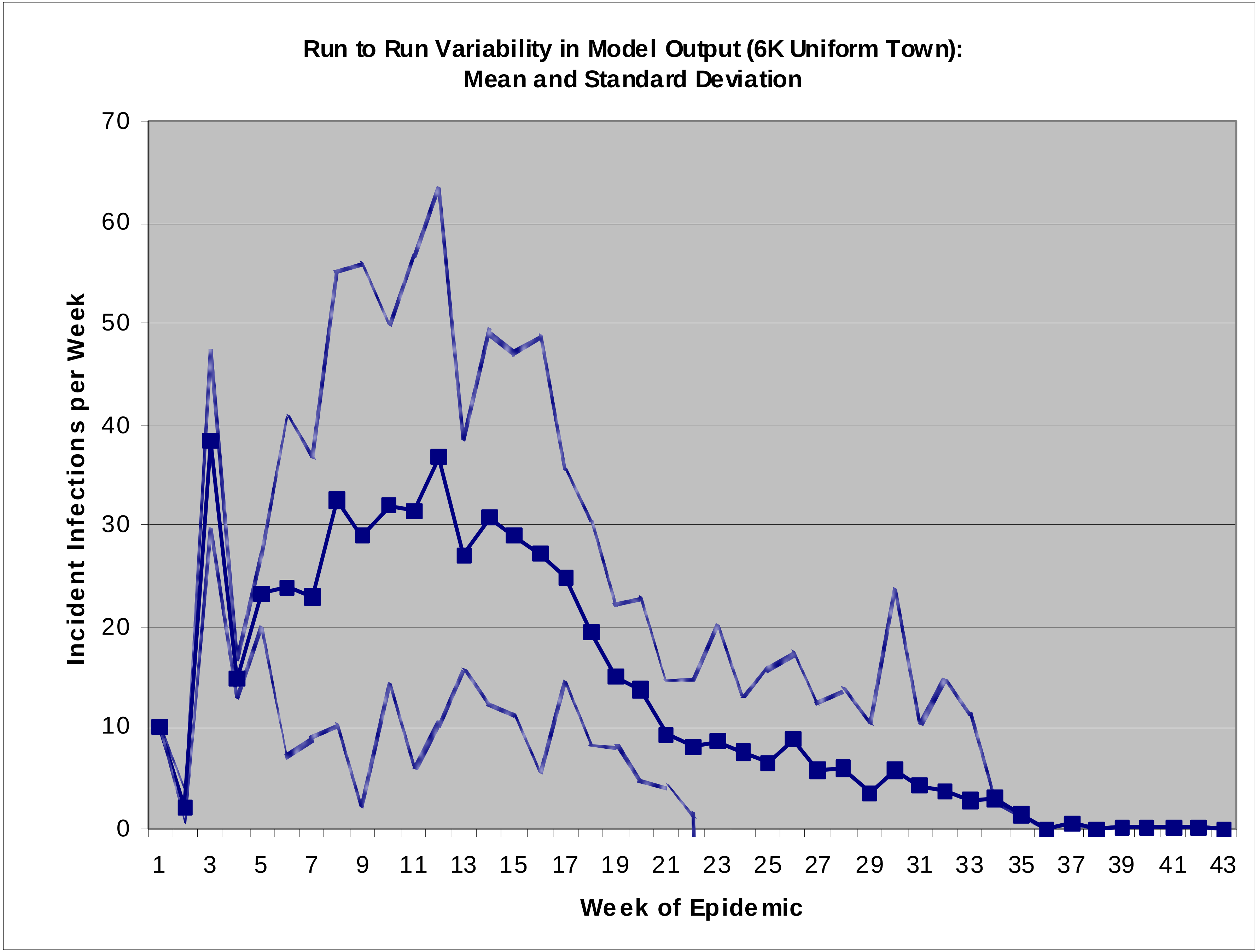
Three variations of more complex social architectures

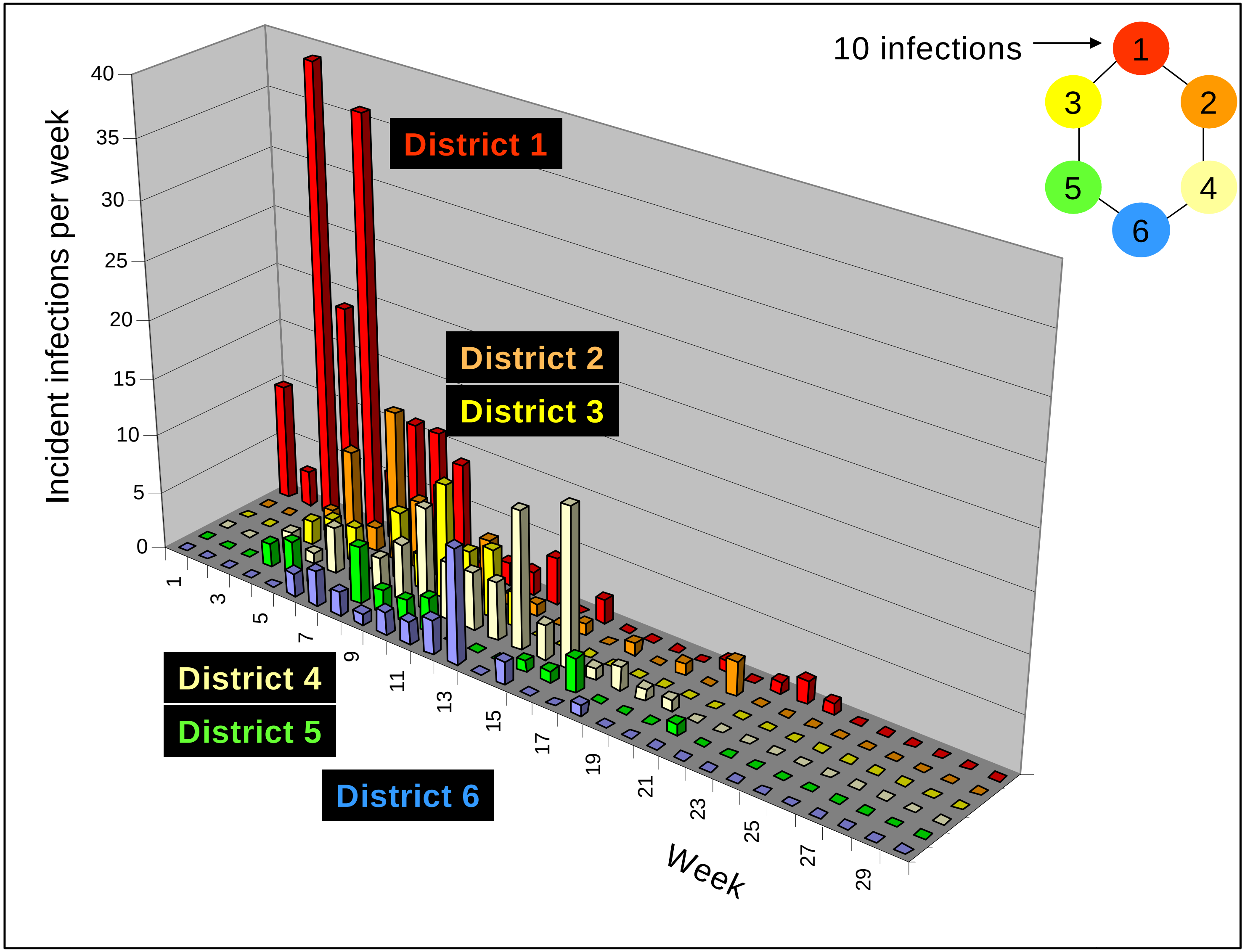
Contact dendrogram of a short-lived epidemic lasting only 2 generations (N.B. only one index case)





Contact dendrogram of a rapidly expanding epidemic (N.B. only one index case)


Run to Run Variability in Model Output (6K Uniform Town):
Mean and Standard Deviation
Incident Infections per Week
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43
Week of Epidemic



Complex percolation of an epidemic through a social structure consisting of six linked districts

Example of Results

<u>Table showing results of simulated epidemics in 6K town, Scenarios 1 through 10, Ring Architecture , 25 simulated epidemics each scenario</u>
(total number of simulations = 10 x 25 = 250 simulated epidemics):

6k Ring

Scenario	Mean Infections	SD	Vaccinated	SD	Deaths	SD	Vac/Inf	Mean Duration	SD Duration
1	5377.7	78.6	0	0	1728.3	36.9	0	298.5	52.5
2	4929.3	108.1	0	0	1588.7	48.3	0	307.7	38.7
3	94.2	34.4	2096.4	393.8	33.1	12.5	22	96.5	23.5
4	106.6	37.6	2200.3	389.3	37.2	11.7	21	105.9	29.3
5	104.2	39.3	2120.8	469.1	35.8	14.4	20	100.9	29.9
6	81.2	21.4	3344.5	220.1	28.8	8.2	41	81.4	17.5
7	74.5	17.7	3322.8	194.1	28.5	7.3	45	81.3	16.7
8	59.4	19.5	4815.6	48.3	20.4	6.8	81	61.5	8.9
9	55.8	13.6	4816.4	47	22.4	5.6	86	62.4	9.1
10	102.8	40.3	2254.1	424.8	35	13.7	22	106.2	28.7

Modeling: Key concepts

- New epidemics are highly *stochastic* (not at equilibrium and not evenly mixed throughout the population)

- Vaccines can protect through
  (1) *Direct protection* of vaccinees
  (2) *Herd immunity* protection of non-vaccinees
  (3) *"Quenching"* of nascent epidemics before they begin

- *Targeting* of vaccination (eg to hospital workers and household contacts) can provide substantial protection to the entire population

- Control strategies (preemptive vaccination, isolation, reactive vaccination) can act *synergistically* to completely quench epidemics

END